植物研究雑誌
J. Jpn. Bot.
80: 176–185 (2005)

A New Marine Diatom *Cocconeis sagaraensis* Hid. Suzuki (Bacillariophyceae) from Japan

Hidekazu SUZUKI[a], Tamotsu NAGUMO[b] and Jiro TANAKA[c]

[a]Aoyama Gakuin Senior High School,
Shibuya 4–4–25, Shibuya-ku, Tokyo, 150-8366 JAPAN;
E-mail: hidekazu@agh.aoyama.ed.jp
[b]Department of Biology, The Nippon Dental University,
Fujimi 1–9–20, Chiyoda-ku, Tokyo, 102-8159 JAPAN;
[c]Department of Ocean Sciences, Tokyo University of Marine Science and Technology,
Konan 4–5–7, Minato-ku, Tokyo, 108-8477 JAPAN

(Received on December 20, 2004)

A new species of *Cocconeis* has been found growing on the brown seaweed *Eisenia arborea* Areschoug from Sagara-cho, Shizuoka Pref. on the Pacific coast of Japan; we propose the name *Cocconeis sagaraensis* Hid. Suzuki and describe the species by light microscopy (LM) and electron microscopy (EM). The main morphological features of *C. sagaraensis* are as follows. The valves are broadly elliptic to almost rhombic. The valve face of the raphid valve (RV) is slightly concave and that of the araphid valve (ARV) is complementary to the RV and convex. The raphe on the RV is straight. A submarginal hyaline area coincides internally with a thickening that follows the valve outline. The RV striae consist of small, round areolae and are radiate and uniseriate. On the ARV, the striae are uniseriate, straight and slightly radiate. The areolae display a very sophisticated structure. The cingula of the both valves consist of at least three girdle bands: a valvocopula and two bands. The RV valvocopula is open at one pole of the cell, and has several hammerhead fimbriae. The closed ARV valvocopula also possesses fimbriae. The relationship between *C. sagaraensis* and similar members of the genus *Cocconeis* is discussed.

Key words: *Cocconeis sagaraensis* Hid. Suzuki, marine diatom, morphology, new species, valve structure.

In marine intertidal habitats, species of the genus *Cocconeis* are commonly found growing on seaweeds (Takano 1962, Edsbagge 1966, Nagumo and Tanaka 1990, 1994, Suzuki et al. 1999, 2000, Suzuki and Kobayashi 2002, Suzuki and Nagumo 2003, 2004), seagrasses (Tanaka 1984), and mangrove roots (Romero and Navarro 1999). Such habitats have recently been the source of many new taxa. For example, Romero and Navarro (1999) recorded *C. caribensis* Romero & Navarro, an epiphyte on mangrove roots (*Rhizophora mangle* L.) in the southeast Pacific Ocean coastal waters; De Stefano et al. (2000) have described *C. multiperforata* De Stefano, Marino & Mazzella on *Posidonia oceanica* (L.) Delile from the Mediterranean Sea, and Suzuki et al. (2001) found *C. shikinensis* Hid. Suzuki from *Caulerpa racemosa* (Forsskål) J. Agardh var. *laetevirens* (Montagne) Weber van Bosse, from the Izu Islands.

Host-epiphyte relationships for *Cocconeis* species are unclear, albeit interesting. This is

due to the fact that the morphological and taxonomic characteristics of *Cocconeis* species are poorly understood. Detailed descriptions and the accurate identification of *Cocconeis* species are essential before the ecology and host preferences of these organisms can be determined.

A new species of *Cocconeis* was found on brown seaweed collected from the coast of Japan. The morphology of this new species, described as *Cocconeis sagaraensis* Hid. Suzuki, was examined by light microscopy (LM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM), and the details are described here.

Material and Methods

The sample of *C. sagaraensis* was obtained from a seaweed *Eisenia arborea* Areschoug (Laminariaceae, Phaeophyceae), collected from the coast of Sagara-cho, Shizuoka Pref., Japan by Dr. N. Katano on 1 April 1983.

The material was treated using the bleaching method (Nagumo and Kobayasi 1990, Nagumo 1995, Osada and Nagumo 2001). The light and electron microscopy techniques were essentially the same as those used preciously (cf. Suzuki et al. 2001). Specimens were examined using HITACHI S-4000 and HITACHI S-5000 SEMs, and JEOL-2000EX TEM.

The terminology used is that suggested by the Working Party on Diatom Terminology (Anonymous 1975, Ross et al. 1979), with additional terms from Round et al. (1990) and Kobayasi and Nagumo (1985).

Results and discussion

Cocconeis sagaraensis Hid. Suzuki, sp. nov. [Figs. 1–32]

Valvae late ellipticae ad fere rhombicae apicibus rotundatis, 23–29 μm longae et 16–21 μm latae. Valva cum raphe concava, raphe recta, area centrali elliptica vel orbiculari, Striis uniseriatis, ad centrum parallelis rectisque, ad apices radiatis leniter curvatis, 12–14 in 10 μm. Valva sine raphe convexa, sterno lineari angustoque, striis uniseriatis, ad centrum parallelis rectisque, ad apices radiatis curvatisque, 5–7 in 10 μm. Interstriae fortiter silicificatae in pagina valvae interna. Valvocopula sine fimbriis.

TYPE: JAPAN; Honshu, Shizuoka Pref., Haibara-gun, Sagara-cho (34°41′N, 138°11′E), 1 April 1983, N. Katano (holotype). [Figs. 1, 2]

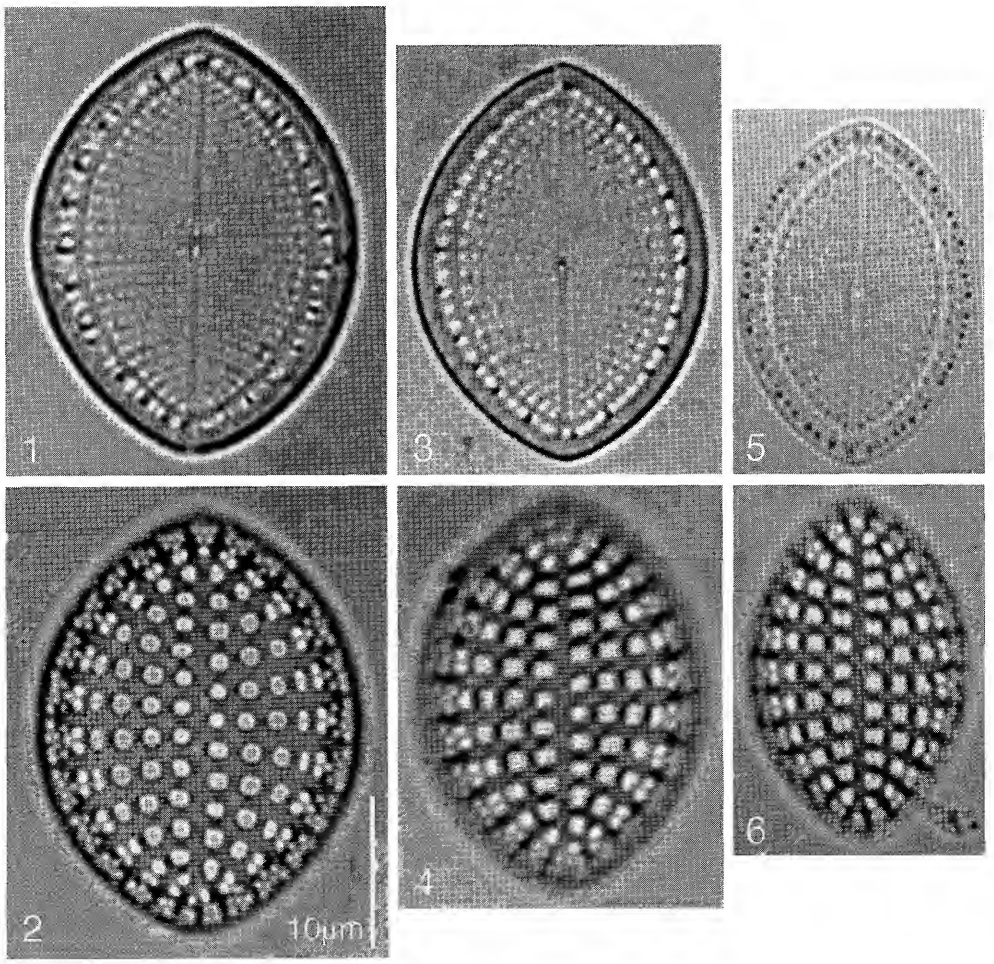
Type slide: BM 101165.

Type material: BM 101165. Epiphytic on *Eisenia arborea* Areschoug (Laminariaceae, Phaeophyceae).

Etymology: The species epithet is derived from Sagara-cho, which is the type locality.

Valves are broadly elliptic to almost rhombic, 23–29 μm long, 16–21 μm wide. The end of valve is pointed (Figs. 1–6). Stria densities at the center of valves are 12–14 in 10 μm on the raphid valve (RV) and 5–7 in 10 μm on the araphid valve (ARV).

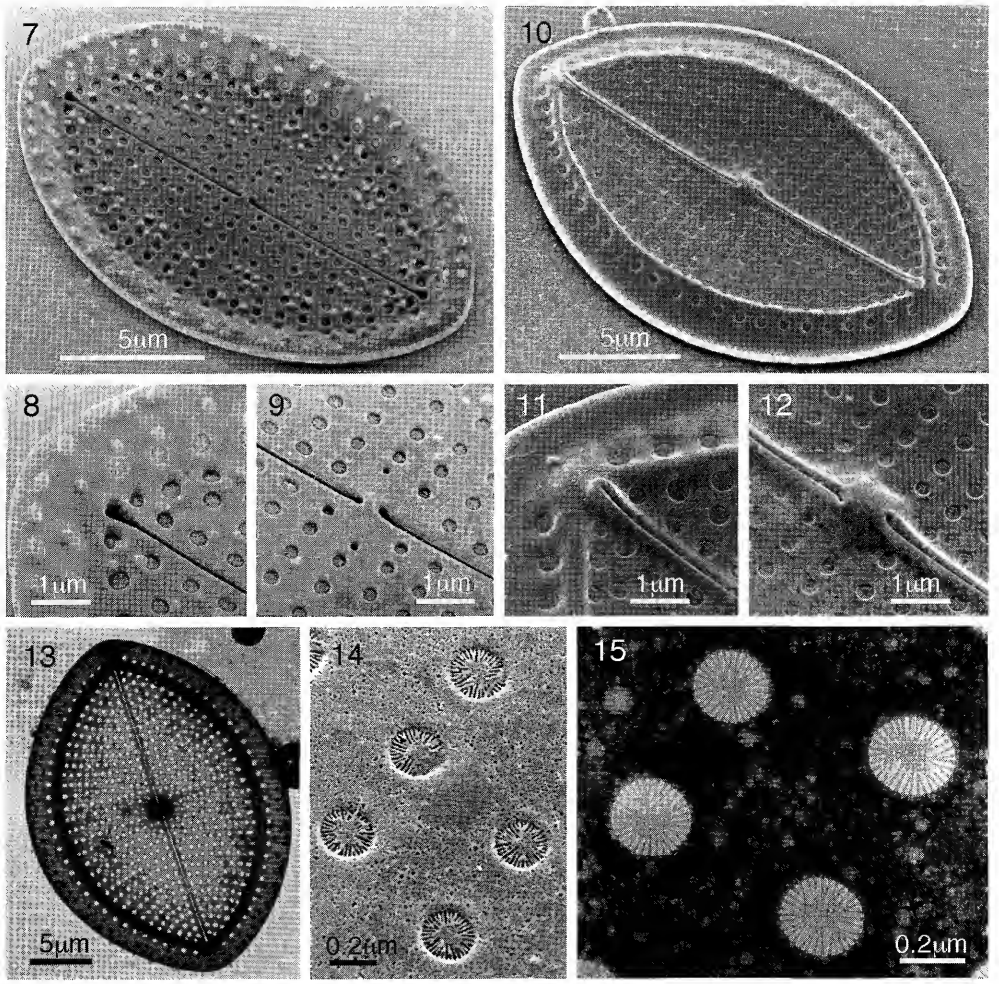
The valve face of the RV is slightly concave. There are many small warty processes on the periphery, from about halfway across the valve from the raphe to the margin on the external surface (Fig. 7). The raphe appears externally as a simple slit, which is straight (Figs. 7, 13). The inner raphe fissures lie in a very narrow, but raised axial area (Fig. 10). Externally, the proximal raphe ends are coaxial and somewhat expanded and pore-like (Fig. 9), but internally they are undilated and slightly deflected in opposite directions (Fig. 12). The distal raphe ends are dilated externally (Fig. 8), but terminate in diminutive helictoglossae internally (Fig. 11). The central area is round, appearing slightly raised internally (Fig. 12). The submarginal hyaline area is hardly recognizable on the external valve surface. On the inside, however, the hyaline area is much more obvious and coincides with a thickening that follows the valve outline (Figs. 10, 11). The striae consist of small round areolae and are radiate and



Figs. 1–6. (LM). *Cocconeis sagaraensis* Hid. Suzuki, sp. nov. Raphid valves (Figs. 1, 3, 5) and araphid valves (Figs. 2, 4, 6) of the same frustules. Holotype (Figs. 1, 2).

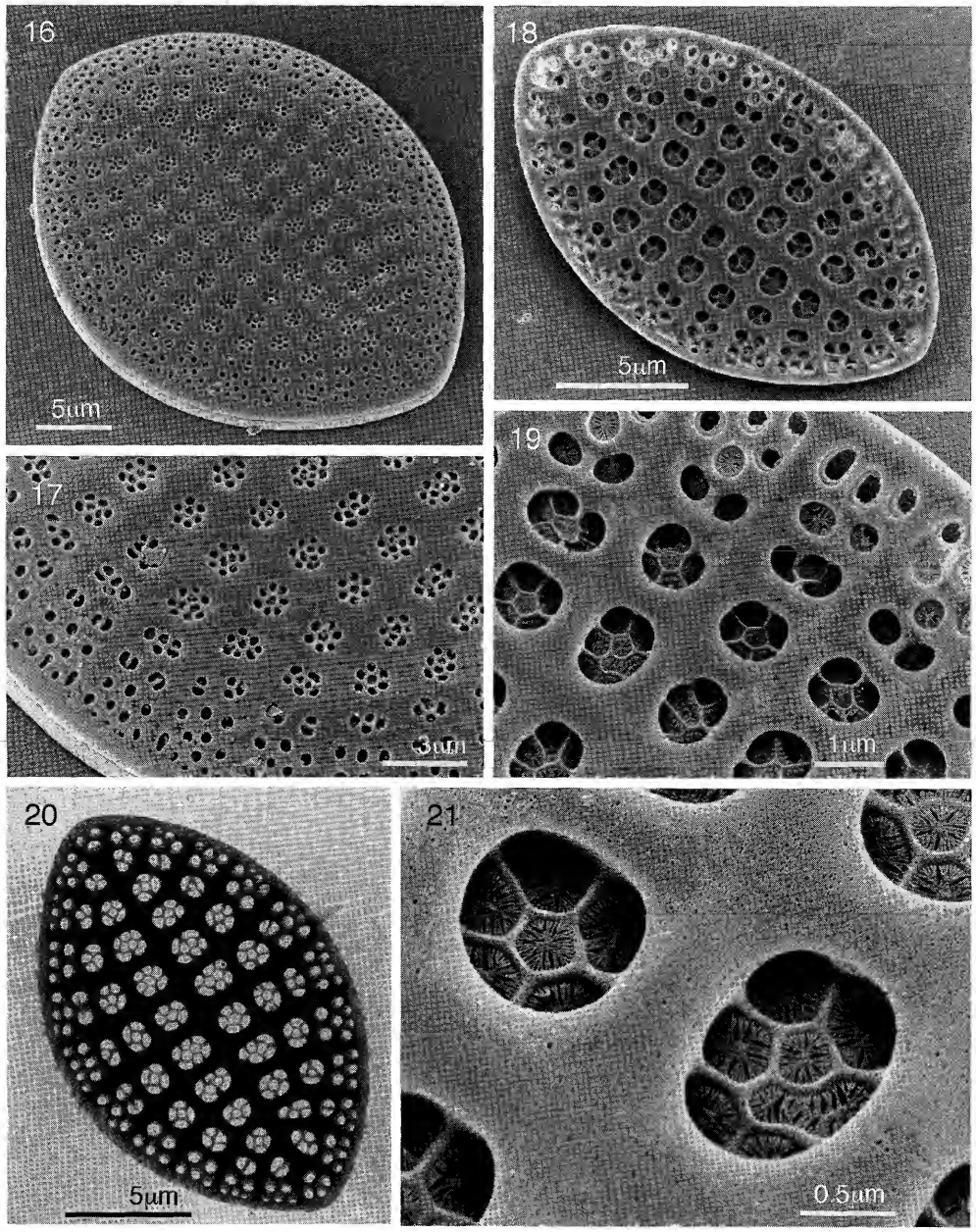
uniseriate (Fig. 13). Each areola is occluded by a hymen with linear perforations, which are radially arranged, with longer and shorter ones alternating (Figs. 14, 15).

The ARV is convex overall (Fig. 16). The axial area is narrow and plain externally (Fig. 16). Internally it is at the same level as the rest of the valve surface (Fig. 18). No central area is present. The striae are uniseriate (Fig. 20), straight and slightly radiate in the center of the valve, changing to radiate and curved towards the apices. The interstriae are developed into prominent costae on the internal valve surface (Fig. 19). The areolae display a very sophisticated structure; internally they are subquadrangular or round and separated by the stout ribs and the interstriae (Figs. 19, 20); externally they are occluded by less robust anastomosing ribs (Figs. 17, 20). Each areola opens externally via 4–10 small circular pores (Fig. 17). The areolae are occluded by hymenes with short linear perforations, that are arranged radially (Fig. 21). This complex

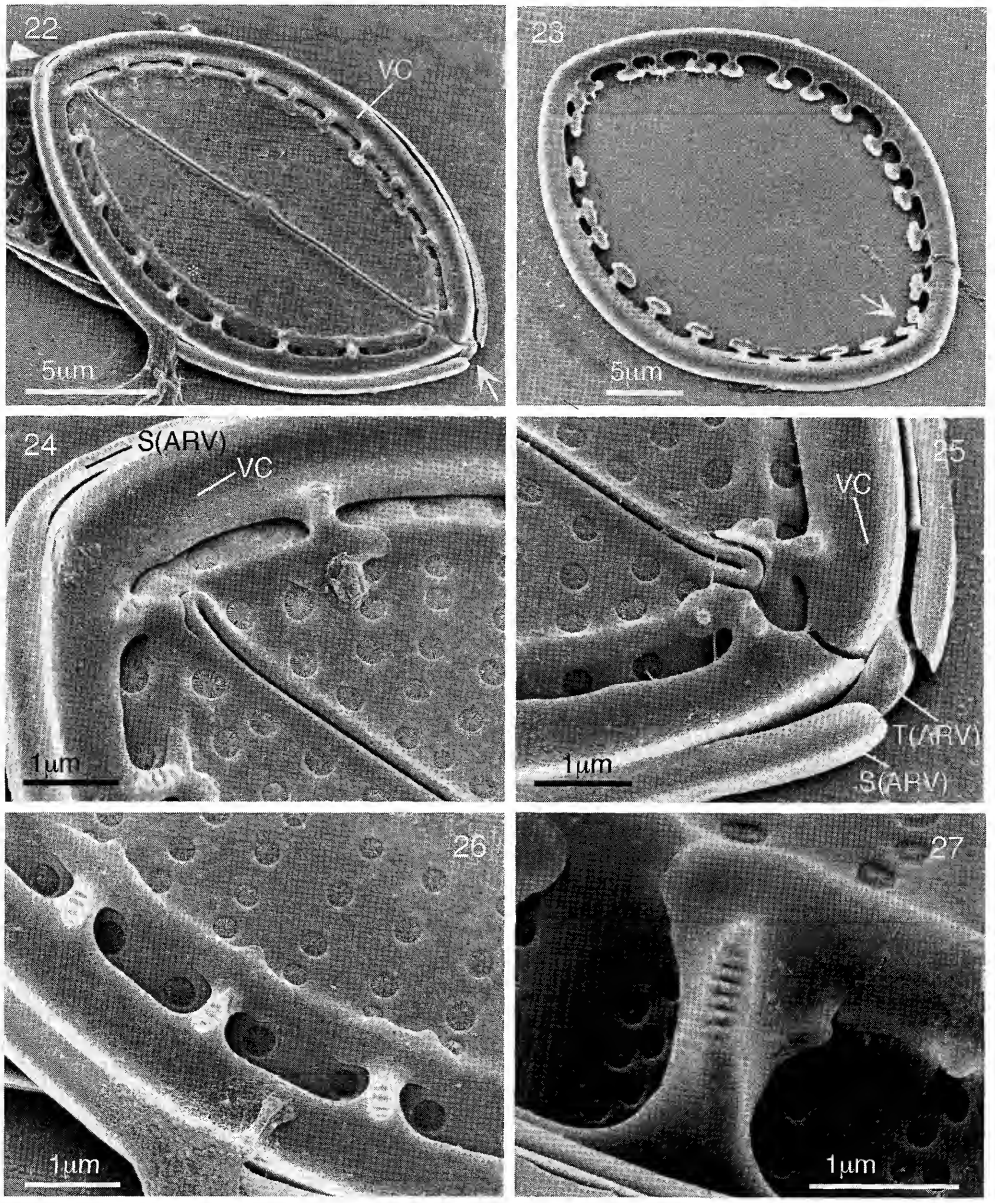


Figs. 7–15. *Cocconeis sagaraensis* Hid. Suzuki, sp. nov. Raphid valves: Figs. 7–12, 14 (SEM), Figs. 13, 15 (TEM). Figs. 7–9. External views of the raphid valve. Fig. 7. Whole valve. Fig. 8. Raphe end in terminal area. Fig. 9. Proximal raphe ends in central area. Figs. 10–12. Internal views of the raphid valve. Fig. 10. Whole valve. Fig. 11. Diminutive helictoglossa in terminal area. Fig. 12. Proximal raphe ends in central area. Fig. 13. Whole valve, showing the straight raphe, the uniseriate striae consisting of small round areolae, and a submarginal hyaline area. Figs. 14, 15. Hymenes with linear perforations in a centric array.

areola structure is quite different from that of *C. scutellum* Ehrenberg var. *scutellum* (Holmes et al. 1982, Romero 1996, Sar et al. 2003, Riaux-Gobin and Romero 2003), but shows some resemblance to *C. scutellum* var. *parva* (Grunow) Cleve (Okuno 1957, Riaux-Gobin and Romero 2003) and *C. scutellum* var. *posidoniae* De Stefano, Marino & Mazzella (De Stefano et al. 2000). However, the complexity of the micro-ornamentation of the areolae in *C. sagaraensis* shows that it is completely different from these two varieties. The ARV of *C. scutellum* var. *posidoniae* has thin interstriae and the



Figs. 16–21. *Cocconeis sagaraensis* Hid. Suzuki, sp. nov. Araphid valves: Figs. 16–19, 21 (SEM), Fig. 20 (TEM). Figs. 16, 17. External views of the araphid valve. Fig. 16. Whole valve. Fig. 17. Marginal area. Figs. 18, 19. Internal views of the araphid valve. Fig. 18. Whole valve. Fig. 19. Marginal area. Fig. 20. Whole valve showing the straight sterunum. Fig. 21. Areolae occlusion. Note the areolae consisting of ovoid, circular and reniform openings. Hymenes with linear perforations in a centric array.



Figs. 22–26. *Cocconeis sagaraensis* Hid. Suzuki, sp. nov. Cingula: Figs. 22–26 (SEM), Fig. 22. Internal view of the raphid valve with a valvocopula (VC). Fig. 23. Valvocopula of the raphid valve showing a open part (arrow). Figs. 24–26. Valvocopula (VC) of the raphid valve, and the second band S (ARV) and the third band T (ARV) of araphid valve remaining on raphid valve. Fig. 24. A closed part (an arrow head in Fig. 22). Fig. 25. Enlargement of the part marked with an arrow in Fig. 22. An open part. Fig. 26. Enlargement of the part marked with an asterisk (*) in Fig. 22. Detail of fimbriae. Fig. 27 (SEM). *Cocconeis scutellum* Ehrenberg var. *scutellum*; Fimbria of valvocopula of the RV.

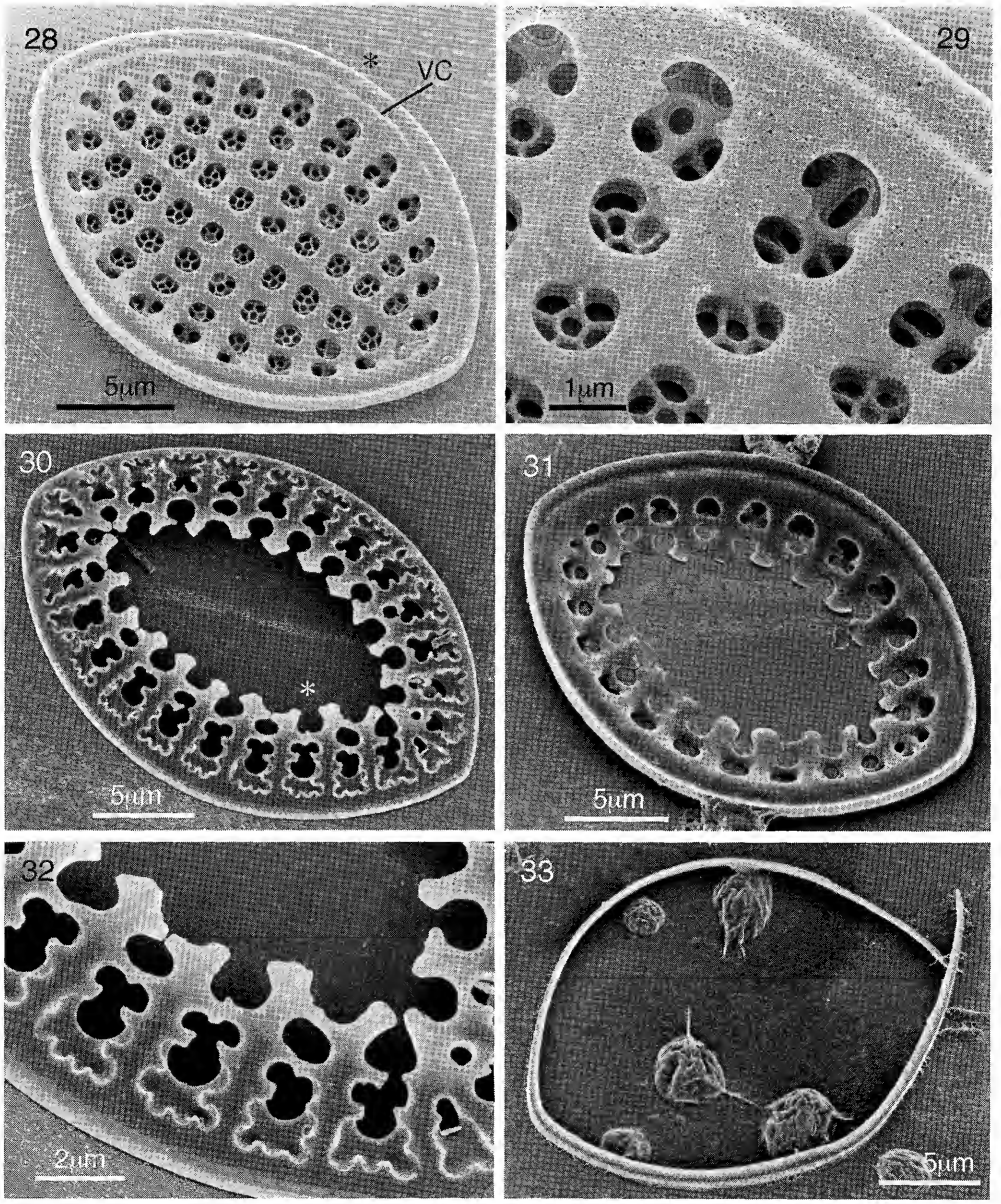
areolae have two to three reniform openings. Unfortunately only a few SEM micrographs of *C. scutellum* var. *parva* are available in the literature. Our observations of *C. scutellum* var. *parva* from Japan (LM photos; Suzuki and Kobayashi 2002, SEM and TEM photos; unpublished data) show that the areolae have one or two circular or elliptic openings in the center and four to six reniform ones around them externally; the inner opening is circular.

The mature cingula of both valves of *C. sagaraensis* consist of at least three girdle bands: a valvocopula and two bands. The morphology of the valvocopula is entirely different in the two valves (Figs. 23, 30, 31). The RV valvocopula bears some resemblance to the equivalent band in *C. scutellum* var. *scutellum* (Fig. 27, Holmes et al. 1982, Romero 1996) and *parva* (Poulin et al. 1984, Riaux-Gobin and Romero 2003). This band is open at one pole of the cell (the equivalent band in *C. scutellum* var. *scutellum* is closed), and has several hammerhead fimbriae (Figs. 22–24), with papillae covered by irregular furrows (Figs. 26, 27; fimbria in *C. scutellum* var. *scutellum*). The closed ARV valvocopula also possesses fimbriae (Figs. 30–32) but these differ in morphology from those on the RV, consisting of a thickened central rib with thinner lateral lobed extensions (Figs. 30, 31). The lobes may be distinct and overlap, or fuse with the lobes of adjacent fimbriae (Fig. 32). Pores in the fimbriae coincide with the areolae in the valve beneath (Fig. 29). The microstructures of these fimbriae resemble those of freshwater species *C. pediculus* Ehrenberg (Gerloff and Rivera 1979, Holmes et al. 1982). The second and third bands are narrower and thinner than the valvocopula, and are open at one pole of the cell (Figs. 25, 33). The second band does not possess a ligula (Fig. 33).

Cocconeis sagaraenesis is morphologically similar to the *C. scutellum* group; *C. scutellum* var. *scutellum*, var. *parva*, var. *posidoniae*, var. *speciosa* (Gregory) Cleve-Euler and var. *ampliata* Grunow, but the new species can be readily distinguished by the following characters: (i) the valve outline is almost rhombic, and the valve poles are pointed; (ii) there are many small warty processes on the external surface of the RV; (iii) the areolae of the ARV display a characteristic, very complex structure; and (iv) the valvocopula of the ARV possesses well-developed fimbriae. The RV of the new taxon is similar to that of *C. scutellum* var. *ampliata* (Grunow in Van Heurck 1880, plate 29, fig. 5), but the ARV (plate 29, fig. 4) is not. The ARVs of this taxon and *C. speciosa* Gregory (Gregory 1855, 39, plate 4, fig. 8), considered as a variety of *C. scutellum* in VanLandingham (1968), are very much alike, but Gregory (1855) did not describe the RV. Poulin et al. (1984, as *C. scutellum* var. *speciosa*) and Snoeijs (1993, as *C. speciosa*) show ARV internal SEM views, but the areola ornamentation is not shown clearly enough to be compared with the new taxon. Therefore, it is difficult to identify this specimen with *C. scutellum* var. *speciosa*.

This species grows abundantly on *Eisenia arborea* in Sagara-cho, Japan; it has been found in only one locality and was not recorded previously (Takano 1962, Edsbagge 1966, Tanaka 1984, Nagumo and Tanaka 1990, 1994, Suzuki et al. 1999, 2000, Suzuki and Kobayashi 2002, Suzuki and Nagumo 2003, 2004).

Thanks are due to Dr. D. G. Mann, Royal Botanic Garden, Edinburgh, who has read through the entire manuscript of the paper and made a number of helpful suggestions. The authors are grateful to Dr. G. Reid and Dr. D. M. Williams, the National History Museum, Department of Botany, London, UK, who have made a number of helpful suggestions regarding preservation of the holotype slide and taxonomy. We wish to



Figs. 28–33. *Cocconeis sagaraensis* Hid. Suzuki, sp. nov. Cingula: Figs. 28–33 (SEM), Figs. 28, 29. Internal views of the araphid valve with a valvocopula (VC). Fig. 28. Whole valve. Fig. 29. Enlargement of the part marked with an asterisk (*) in Fig. 28. Detail of fimbriae. Figs. 30–32. Valvocopula of the araphid valve. Fig. 32. Enlargement of the part marked with an asterisk (*) in Fig. 30. Detail of fimbriae. Fig. 33. The second band of araphid valve.

thank Dr. N. Katano, Akita Prefectural University, Faculty of Bioresource Sciences, Japan, who supplied samples treated herein. This study was supported by a Grant-in-Aid for Scientific Reserch (no. 15570087) from the Ministry of Education, Science, Sports and Culture, Japan and the Mikimoto Fund for Marine Ecology, Japan.

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鈴木秀和[a]，南雲　保[b]，田中次郎[c]：**本邦沿岸からの海産珪藻の1新種, *Cocconeis sagaraensis***

静岡県相良町沿岸で採取したサガラメ（*Eisenia arborea* Areschoug）に着生していた新種 *Cocconeis sagaraensis* Hid. Suzuki の光学顕微鏡および電子顕微鏡（TEM, SEM）による殻微細構造を観察した．殻は幅の広い楕円形あるいは菱形で，殻端はやや尖る．縦溝殻：殻面はわずかに凹状で，表面に多数の小さないぼ状突起がある．殻縁近くには明瞭な無紋域があり，内面で肥厚する．縦溝は直線状．無縦溝殻: 殻面はやや凸状にふくらみ，低い台形をなす．胞紋は，殻の外面に4–10個の小さい円形の開孔をもち，縁に沿って放射状に配列する短い穿孔を持つ薄皮により閉塞される．帯片: 両殻とも少なくとも3枚の帯片からなる．縦溝殻ので接殻帯片は片端開放型で数個のハンマーの頭状突起をもち，無縦溝殻のそれは閉鎖型で鋸歯状突起をもつ．形態的には，本種は *Cocconeis* 属のタイプである *C. scutellum* Ehrenb. に似ている．しかし，*C. scutellum* は殻が楕円形で殻端が尖らず，縦溝殻の殻表面にいぼ状突起を欠き，無縦溝殻の胞紋は1個の円形の開孔をもつ点で，本種と異なっている．

([a]青山学院高等部，
[b]日本歯科大学，
[c]東京海洋大学)